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Archaeology at the micro-scale: micromorphology and phytoliths at a Swahili stone-town

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Abstract

Geoarchaeological and archaeobotanical techniques are increasingly applied to the study of urban and domestic space. However, they are seldom performed as part of an integrative approach, where the soil and botanical micro-records are used together. This paper presents the preliminary results of ongoing research at Songo Mnara in Tanzania that combines customised intra-site soil macro- and micromorphological analyses, chemical analysis and the study of phytoliths. The research is part of a multidisciplinary project on the use of urban space in Swahili stone-towns. By eliciting multiple datasets from Songo Mnara, this paper illustrates the potential of integrating geoarchaeology and archaeobotany to investigate the use of space in urban contexts. The approach is a novelty within the context of Swahili archaeology and an emerging one in Africa.

Keywords: Geoarchaeology, phytoliths, domestic space, Swahili

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Introduction

The use of domestic and urban space in archaeology is commonly investigated through the study of cultural materials (e.g. pottery), architecture, and biological macro-remains (e.g. seeds, bones). These types of records provide information on several domestic activities, but further contextual data is necessary to qualify the use of space and the site formation processes at work in archaeological contexts.

When communities establish themselves on a new area, the soil natural processes are modified. For instance, roofs limit the action of weathering and erosion, and favour the enrichment of soils and sediments by chemical compounds originating from domestic activities (Barba 2007). Some indicators of human activities are not macroscopic in their evidence and, thus, cannot be detected during excavation. Therefore, there is the need for implementing sampling strategies suitable for the retrieval of complementary datasets, both at macro and micro-level.

With the aim to further research in this area, intra-site geoarchaeological and micro-archaeobotanical investigations were undertaken as part of the University of York/Rice University archaeological project on urban space at Songo Mnara, Tanzania (www.songomnara.rice.edu). The study of microstratigraphy, employing chemical and phytolith analyses together with soil micromorphology aimed at characterising the natural soils/sediments and the occupation deposits. A total of 127 samples were investigated (74 bulk samples, 42 phytolith samples, and 9 thin sections) creating a broad dataset for understanding depositional processes and domestic activity input in Swahili stone-towns of the East African coast. This paper discusses the results originating from a selection of samples in order to address the integration of different methods to enhance the identification of anthropic markers in open areas and internal domestic space.

The island of Songo Mnara is part of the Kilwa archipelago on the southern coast of Tanzania (Fig. 1), which was occupied for not more than 200 years between the late 14th and the early 16th century. The impressive archaeology of this site includes several large domestic room-blocks, mosques and tombs (Garlake 1966). The multidisciplinary research programme at Songo Mnara (Wynne-Jones and Fleisher 2010) offered an excellent opportunity to explore the potential of integrating geoarchaeological techniques and the study of phytoliths in an urban context within a tropical environment.

Geoarchaeology and archaeobotany in urban contexts

Geoarchaeology is now routinely applied for investigating anthropic signatures preserved within soils and sediments (French 2003; Goldberg and Macphail 2006; Macphail and Goldberg 2010). Geoarchaeological techniques, such as soil micromorphology and chemical analyses, allow the study of ephemeral, poorly preserved or simply non-visible evidence of past human activities. The combination of these techniques plays a pivotal role in disentangling aspects of both domestic and urban life in the past (e.g. Courty et al. 1989; Matthews 2010; Shahack-Gross et al. 2005). For instance, micromorphology studies of building material (e.g. plaster, mortar) have revealed unexpected scenarios such as the evidence for rooms kept clean when they were in use at Çatalhöyük in Turkey (Matthews et al. 1996) and the presence of ‘white’ floors made of tufa (as opposed to burned lime) at Huizui in northern China (Macphail and Crowther 2007).

The principle behind the application of soil chemistry in archaeology is that the presence and content of specific elements in soils/sediments can be associated with human activity. Strontium, for instance, may concentrate in food preparation and consumption areas where abundant bone and shell fragments occur, but also it accumulates in leaf litter and where organic matter and/or ash are deposited (e.g. Knudson and Frink 2010; Ottaway and Matthews 1988). Among the suite of chemical analyses employed in archaeology, Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) is increasingly utilised to map element concentrations relating to domestic activities (e.g. King 2008; Luzzadder-Beach et al. 2011; Wilson et al. 2009).

Similarly, archaeobotany has developed several techniques to study micro-remains in urban and domestic contexts. In particular, phytolith analysis has been able to refine several aspects concerning the use of plants in the past (e.g. Piperno 2006). Phytoliths are microscopic silica particles that originate in different parts of the plant and are released into soils/sediments upon decaying of the organic matter. Phytoliths preserve in most conditions and their morphology can be diagnostic of plant group, family and, rarely, species. The assemblages are sensitive to plant input and when taphonomic processes are under control, they can be an important indicator of the source of vegetal material, the processes this material underwent, and the place where these happened. Recent applications include research into the use of wild and domestic plants in urban sites (e.g. Albert et al. 2008; Madella 2007; Tsartsidou et al. 2007). These phytolith studies allowed the identification of activities (such as crop processing, hay storage and possible animal penning) within settlements, which could not have been identified by macro-remains or context. At Kilise Tepe in Turkey (Madella 2007), it was possible to further comprehend pit construction strategies (e.g. pit lining) and the types of stored goods. In addition, the study of articulated phytoliths (silica skeletons) gave the possibility to highlight the use of *tribulum* in crop processing, specifically in deposits from the courtyards. Therefore, the use of micro-botanical remains augmented the understanding of the role specific architectural space and/or constructs, the spatial division of activities, and the choice of resources.

The integration of geoarchaeological and archaeobotanical methods to the study of domestic and urban spaces is a very recent development and, so far, mainly confined to European contexts and sites in the Near East and North America. Soil micromorphologists have sought to explore the possibility of studying phytoliths observed in thin section to investigate the nature and processing of building materials and occupation deposits (e.g. Albert et al. 2008; Devos et al. 2009; Matthews 2010; Shahack-Gross et al. 2005). These approaches offer the great advantage of allowing the observation of phytoliths *in situ*, embedded in their micro-context. However, the nature of soil thin sections limits significantly any attempt at qualifying and quantifying the phytolith evidence compared with the possibility offered by conventional phytolith analysis. On the other hand, conventional analysis involves the destruction of the embedding material in order to extract phytoliths from soils/sediments. This means that potentially significant information on the micro-context is lost during the sample processing.

It follows that an integration of these high-resolution techniques may well help in overcoming some of their limitations. To date, such integrative approaches have made only cameo appearance, though studies are increasing as well as protocols (e.g. Madella and Lancelotti 2011). Shillito et al. (2008) have been able to elucidate important aspects of midden formation by combining soil micromorphology, phytolith analysis and other high-resolution techniques (infra-red and organic residue analyses). Further success has been obtained in the investigation of hunter-gatherer open-air sites, where ethnographical observations were matched with the evidence from the phytolith record for disentangling the depositional histories of shell middens (Briz Godino et al. 2011).

Research at Songo Mnara: methods and results

To explore further the potential of combined geoarchaeological and phytolith approaches to the study of urban space, research at Songo Mnara has applied a multiple contextual approach, spanning from open areas to habitation space. The twin aim was to define broadly the site's deposits and to provide finer details on excavated contexts and sediments by combining systematic sampling of open areas and expedient sampling of specific archaeological deposits.

Two main open areas were selected for systematic soil/sediment cover recording and sampling: the South Open Area and the North Open Area (Fig. 2). These areas are located within residential compounds and, thus, they were selected as representative of the open space used by the ancient inhabitants of the site. The regional sediment was sampled for reference using a grid of 5 x 10 m square laid across the two open areas. Within the site, sediments were sampled at 5 m intervals over four E-W transects and from approximately 10 cm below the ground surface. The 5 m interval between sampling spots was considered appropriate for recording spatial variability at the site with ground surface covered by low grasses and patches of tree plants located at the margins. The sampling depth was chosen in order to characterise deposits comprised between the topsoil surface and the subsoil. The almost flat landform together with sparse grassland vegetation suggested a limited variability in topsoil thickness. Furthermore, ethnoarchaeological research has shown the benefits of subsurface sampling for investigating open space around houses (see Hutson et al. 2007)

Two further reference samples were collected. One reference sample was taken from the surface of a field in the uplands of the island where finger millet (*Eleusine coracana* Gaerth.) was growing at the time of the sampling. The area is covered by the regional sediment (see below), and crops were nearly ready for harvesting at the time of the sampling. The second reference sample comes from a modern lime-pit located in the upper part of the island, where coral is processed today to obtain lime. Archaeological contexts were sampled at House 44, a self-contained, small structure located in the northern part of the site (Fig 2). The structure was excavated in its entirety (Wynne-Jones and Fleisher 2010), and soil sampling was carried out during the excavation. The sampling strategy was opportunistic and was driven by context-specific conditions such as room fills, habitation surfaces and building material. As the latter was of particular interest, a plastered floor and a fragment of plaster were analysed.

The samples were processed for soil micromorphology, chemistry and phytolith studies. The protocols of the laboratory analyses are presented in the Appendix. Soil chemical properties were characterised via pH determination and ICP-AES (Inductively Coupled Plasma Atomic Emission Spectroscopy) multi-element analyses (34 elements). In order to qualify the microstratigraphy of selected contexts at House 44, nine samples were processed for micromorphological analysis.

Phytolith were extracted, identified and quantified from samples from the open areas, room fills and floors inside the house. The current absence of a phytolith reference collection for this area of the world means that phytoliths have been grouped according to tried-and-tested categories that, even if not expressing the highest possible level of taxonomic meaning, are significant for the current study of methodological exploration (Table 1):

1) Grass morphoypes – produced by all grasses, including forms diagnostic of grass subfamilies. These group was subdivided according to Poaceae sub-families morphotypes:
    a. Pooid
    b. Panicoid
    c. Chloridoid
2) Non-grass morphotypes – all forms that are not produced by grasses. This group was subdivided in:
    a. Woody morphotypes (originating from woody plants)
    b. Palm morphotypes (Arecaceae)
    c. Woody/herbs morphotypes (ubiquitous in the two groups)
3) Other morphotypes – forms that cannot be related to any specific plant group, mostly because their origin is poorly understood.

Field observations, concentrations of selected chemical elements and phytolith counts are presented in Table 2, and summary micromorphological descriptions are provided in Table 3.

Regional sediment and control samples

The regional sediment is a reddish brown, medium to fine textured sandy loam that originates from the weathering of coral limestone, which is the main geological unit of the island. The regional sediment is characterised by relatively low concentrations of plant nutrients, such as phosphorus (<1500ppm) and zinc (<10ppm). The phytoliths extracted are predominantly from grasses (86%) with few non-grass morphotypes (12%)

The reference sample from the modern finger millet field yielded high concentrations of aluminium (3.5%), barium (280ppm), chromium (39ppm), iron (1.7%), and manganese (474ppm), and plant nutrients such as calcium (0.4%) and phosphorus (330ppm) were found in low quantities. The phytolith assemblage is again characterised mostly by grass cells (73%) with a few non-grass morphotypes (14.5%).

Multi-element analysis on the reference sample from the lime pit indicates high contents of calcium (34%) and strontium (8550ppm) and low amounts of other plant nutrients (e.g. barium 10ppm, phosphorus 110ppm, zinc 2%). No phytoliths were recovered from this sample.

Open areas

Two main sediment types were recorded across the open areas (Fig. 2): the regional sediment and a brown silty sandy loam. The chemical and phytolith data from the regional sediment are summarised above (see also Table 2). The brown silty sandy loam was recorded in patches across the open areas of the settlement and within the excavated structures. It is characterised by very high concentrations of plant nutrients (e.g. calcium >20%, phosphorus >3000ppm) and it has, at places such as in Transect 2 of the South Open Area (SOA), an ashy colour and a high content of charcoal (Table 2)

When the chemical and phytolith data form each open area are analysed together, with no division between different sediment types, a series of patterns can be identified. The limestone is responsible for the generally alkaline conditions (pH >8) found at the site. In general, high contents of phosphorus (>3000ppm) and strontium (>3800ppm) were detected in the open areas. However, phosphorus is higher in the SOA and peak values (>3000ppm) are usually associated with the dark brown silty loam, often matching high concentrations of manganese (>150ppm). Other chemical patterns are associated with metal elements. Copper and cobalt (both >2ppm) are found in comparatively high presence in the North Open Area (NOA), and the SOA is, instead, characterised by a high amount of lead (>5ppm) and the only significant occurrence of silver (<0.7ppm).

Grass phytoliths dominate the assemblages from the open areas and no significant difference in the concentration of subfamily morphotypes was recorded. Non-grass phytoliths (especially woody morphotypes) are more abundant in the NOA (20.9%; SOA 8.7%). In addition, calcium oxalates were present in the phytolith slides. The phytoliths extracted from the ashy colour patches of the SOA denote both a grass and non-grass input (Table 2). Pooid cells are the most common grass morphotypes, and other grass subfamilies (Panicoid and Chloridoid) are poorly represented. The majority of non-grass phytoliths originated from woody plants, while woody/herbs morphotypes are present in small number.

Domestic contexts: House 44

At House 44, bulk samples were collected from the fills and floors of the Central Room (SM004), the Southwestern Room (SM001) and the Back Room (SM010). In general, the samples yielded relatively high contents of calcium, sulphur and strontium (Table 2). The phytolith assemblages from the house contexts are dominated by grass morphotypes (and within this group, Pooid cells). Non-grass phytoliths are generally few but nonetheless are present in all the samples. Significantly, palm phytoliths have been recovered from all the deposits.

In the Back Room (SM010), context 10037 shows a peak in phosphorus (9900ppm) and zinc (65ppm) and a comparatively high concentration of copper (9ppm). The same context yielded a high amount of non-grass phytoliths (26.1%) with a significant number of palm morphotypes (12.4%). This midden deposit was covered by a packed earthen surface (context 10002) that also yielded high contents of phosphorus (>2600ppm), zinc (>11ppm), chromium (>12ppm), and manganese (116ppm). The phytoliths associated with this context are predominantly from grasses (89.1%) and the Pooid sub-family morphotypes (27.5%) are the most common. The non-grass component (9%) features mostly woody/herbs phytoliths (2.9%) with a few woody (1.9%) and palm (0.9%) morphotypes. Several fragments of baked clay were present in this context and a sample of backed clay was then processed for micromorphology analysis. The thin section (SM10, context 10002#3; see Table 3) exhibits an iron- and clay-rich fabric with few fine quartz fragments. Organic matter is observed in small quantity and it is mostly amorphous with rare occurrences of fungal spores, pollen, and microcharcoal. The colour variation characterising the fine groundmass is probably due to different firing temperature, and the darker colour of the fabric is the result of strong iron (and possibly manganese) impregnation.

Building material

Sample #1 (SM001 Context 1002) was collected from a plastered floor about 12 cm thick (23–35 cm below the ground) in the Southwestern Room. Multi-element analysis shows peaks in calcium (33%) and strontium content (6120ppm). The phytolith assemblage includes roughly equal proportions of grass (44.6%) and non-grass (33.5%) morphotypes. Noteworthy, woody phytoliths (31.9%) account for the majority of the non-grass component.

The thin section from the same deposit revealed a matrix dominated by fine-textured sandy material composed of silt, fine and very fine fragments of coral with very few quartz fragments (Table 3). A few coarse fragments of coral and shell are also present The fine groundmass is calcitic, composed mainly by microsparite crystals of calcium carbonate, which form by the evaporation of the soil moisture and deposition of neo-formed or re-precipitated calcium carbonate within the pores. The limited porosity is dominated by vesicular voids, which occasionally exhibit horizontal patterns. Organic matter includes little amount of fine charcoal and microcharcoal. A distinctive type of reddish, organic-rich material is occasionally seen, especially toward the bottom of the slide. This is composed of very fine amorphous excremental matter and moderately iron-rich clay with little microcharcoal. Two distinctive types of coral fragments were observed: 'fresh' coral and 'calcined'coral (Fig. 3). 'Fresh' is used to refer to coral that show no particular distinctive features. At microscopic scale, fragments of 'calcined' coral exhibit a distinctive fabric with lumps and aggregates. Both types of coral are evenly distributed in this sample, as it is the case for the thin sections from other contexts (e.g. SM004 contexts 4009 #7; see discussion below).

Sample #7 (SM004 context 4009) was collected from a burning feature associated with a concentration of potsherds in the NW corner of the Central Room (Fig. 3). Multi-element analysis revealed high contents of calcium (23%), iron (0.3%), sulphur (0.1%), phosphorus (2520ppm), and strontium (4190ppm). The phytolith extracted are predominantly from grasses (91%) with few non-grass morphotypes (5.9%). Pooid morphotypes (29%) account for the majority of the grass phytoliths and the non-grass component is characterised by a minor increase in woody/herbs (2.9%) and palm (0.2%) phytoliths. The micromorphology sample consists of large fragments of plaster cemented by a medium to fine-textured matrix (Table 3). The plaster fragments belong to the same types of plaster observed in the Southwestern Room (SM001 context 1002 #1) and discussed above. The cementing matrix is essentially composed by calcite and exhibits a crumb microstructure and crystallitic b-fabric. The mineral fraction includes microsparite crystals and crystal intergrowths with rare medium to fine, angular quartz. The fine groundmass is highly bioturbated and is characterised by predominant amorphous iron and organic matter, common microcharcoal, and fine to very fine charcoal. In addition, shell fragments and plant tissues are also relatively common, and fragments of straw are present. Tabular, medium fragments of (charred?) bone, fungal spores, pollen (globular grains), and phytoliths (grass cells) were also observed.

Discussion

Coral limestone and quartz are the main mineral component of the sediments investigated at Songo Mnara. The reddish sandy loam recorded in the open areas and described as regional sediment is mainly composed of fine sands and silt with common coral pebbles, and clay is scarcely present. This mineral composition was also observed in material originating from the weathering of coral outcrops. In particular, coral outcrops are common on the upland and, often, found in fully exposed positions. It is suggested that the reddish sandy loam recorded at the site derives from a *terra rossa* soil. *Terra rossa* soils developed on limestone bedrock are common along the Swahili coast (Pollard 2008).

The other type of sediment documented at the site is an organic-rich, dark, brown silt sandy loam that is frequently found associated with cultural deposits (either visible on surface or buried). The origin for this sediment is not clear yet, but it is undeniable that it has a strong anthropogenic component and is associated with the occupation of the site.

Soil chemistry and phytoliths in open areas

The chemical signature from the open areas shows relatively high contents of phosphorus, manganese, and strontium. Phosphorus is higher in the South Open Area (SOA) and peak values are associated with the dark brown silt sandy loam, where there are also high concentrations of manganese. Phosphorus accumulates by biological deposition and is relatively resistant to leaching in alkaline environments, such as at Songo Mnara. In non-habitation contexts, high levels of phosphorus, and to certain extent manganese, have been related to animal browsing, possibly ruminants that excrete both phosphate and manganese at a much higher rate than humans do (see Gardner and Holliday 2006; Ottaway and Matthews 1998). The thin sections examined show no clear evidence for the presence of phosphate, however these come from house deposits and not from the open areas.

The phytolith analysis revealed that the open areas (and especially the eastern side of both) are characterised by grass leaves and culm (elongated smooth/sinuate morphotypes) with a virtual absence of inflorescence phytoliths. A high concentration of culm/leaf phytoliths may possibly point to the deposition of animal dung and/or the use of grass fodder (straw from cultivated crops or hay) in this area. The presence of fodder might be signalled also by the woody plants phytoliths (more common in the NOA than in the SOA). Indeed, the patches of organic-rich, dark brown silt sandy loam spread across the open areas can be related to the presence of stabulation areas. Palm phytoliths are rarely observed in the assemblages indicating that palms were not common in the areas in-between buildings in the past, contrasting the widespread presence of today.

The origin of metal elements in the open areas is still unclear. Copper and cobalt were found in comparatively high presence in the NOA, and a slightly high amount of lead and the only significant occurrence of silver were recorded in the SOA. High concentrations of metal elements are expected where metal metal-bearing material (e.g. metal objects, pigments, tanning salts?) is present and/or processed. Alternatively, this elemental signature may be the result from the trampling of people (and animals?) that were in contact with or involved in metal-bearing resource processing.

Markers of domestic activities

The samples from the room fills are generally rich in organic matter (plant remains, charcoal, bones, and shell fragments) and plant nutrients. The variety of components and preservation conditions observed in the thin sections suggest that most of this organic matter is associated with the occupation of the house, rather than being the result of post-depositional processes. Even though bioturbation (by soil micro-fauna) has been active, the resulting mixing seems to be localised.

In general, the phytolith assemblages from the house contexts are predominantly of the grass type with a limited but significant presence of non-grass phytoliths. Among the grass morphotypes, Pooid cells from leaves are the most common, while phytoliths from grass inflorescences are again virtually absent. This evidence points to the use/storage of clean grains in the houses. In this respect, it is worth mentioning that also the open areas input lacks evidence for inflorescence phytoliths, possibly suggesting that all the crop processing stages were happening outside the settlement (in the fields?).

The results hint to different activities taking place in each room. In the Southwestern Room, the abundance and nature of organic matter observed in thin section, such as bone fragments (burnt and not burnt) and plant tissue remains together with the concentration of plant nutrients such as calcium and strontium detected by multi-element analysis point to storing/processing of food.

In the Central Room, the micromorphological sample from the burning feature revealed a low content of animal and plant remains. In thin section, the structure and composition of this deposit are different from those commonly observed in hearths used for food processing (cf. Shahack-Gross *et al*. 2004). The deposit consists of plaster fragments (collapsed?) embedded within a calcitic matrix with high contents of charcoal and amorphous iron and organic matter that may have been associated with processing of inorganic materials involving burning, perhaps on occasional basis (?). The phytoliths from this deposit are predominantly of the grass types with a minor component of non-grass morphotypes as it is the case for the sample from the doorway in the Central Room. Significantly, the phytolith assemblages from the Central Room yielded almost half of the amount of non-grass phytoliths recorded in the Southwestern Room.

In the Back Room, the high contents of key elements (phosphorus, chromium, manganese, zinc) in the packed earth floor suggest an input from organic-rich material. Once again, the phytolith signature is similar with the record from the other rooms of predominant grass cells and a small number of non-grass morphotypes. However, contexts 1035 and 1037 yielded a high presence of woody phytolith that points to the presence of wood and/or woody plants.

Plaster

The micromorphological study indicates that the fabric of the plaster is 'calcined' (incomplete decomposition of limestone), a condition produced by burning and a known process employed to produce calcium oxide (or quicklime) from calcareous material, such as limestone and tufa (Karkanas 2007). This process requires heating rock fragments to a steady temperature (800–900°C) with the duration of burning dependent upon the volume of the material. During heating, the decomposition begins at the surface of the rock fragments and slowly penetrates in the core (Karkanas 2007; Kingery et al. 1988; cf. also Shahack-Gross et al. 2005). However, lime can be obtained in a few hours by heating porous, soft calcareous material at temperatures no higher than 800°C (Goren and Goring-Morris 2008; Karkanas 2007). The burning of limestone would then produce a finer-textured plaster material. Once applied, the plaster can be smoothed or burnished to produce a fine and non-porous surface. Burnishing affects the setting of the plaster by altering the exterior surface of the fabric by compression, collapsing the pores and creating 'step-like' cracks (Semple 2006).

The thin sections from Songo Mnara show two types of coral fragments provisionally described as 'fresh' and 'calcined'. The 'calcined' (or heated) fragments are characterised by a fabric of lumps and aggregates. This becomes evident when different fragments of coral are compared (Fig. 3). The heating transformed the original coral microstructure with partial collapse of the pore walls and development of a new pore network. The degree of rubification (iron-staining) and the presence of charred plant remains also point to burning. Furthermore, woody phytoliths are remarkably abundant in the plastered floor, and they probably originate from the wood used for heating the calcareous stones. Early production of quicklime normally occurred in open structures or kilns where fuel and limestone were layered (Platt 1978) to maximise the exposure to heating. The result was often a mix, at least at microscopic level, of quicklime and charred wood. At Songo Mnara, stony coral[1] offers an optimal source of calcareous material that is quarried today to obtain lime. At the lime-processing site visited, it was possible to observe the use of massive wood platforms (5–9 m in diameter) for burning coral using mangrove wood. The use of quicklime plaster at ancient Songo Mnara finds echo in 16th century historical sources, which describe the lime-

[1]Stony coral are commonly found in coral reefs; the latter are essentially large structures composed of coral skeletons and held together by layers of calcium carbonate.

making process involving the use of large wood logs piled in circle wherein coral limestone was burned (Freeman-Grenville 1962: 107).

At microscopic level, the vesicular porosity and the amount of voids infilled with sparitic crystals may be related to wetting and drying cycles. In this respect, the relatively high content of sulphur detected in the burning feature of the Central Room may derive from the decomposition of organic matter in anaerobic conditions. If this is the case, the sulphur concentration would suggest that a certain degree of wetness associated with the sediment from this context.

Conclusion

The proposed approach is novel both in methodological terms and in the area of application. As mentioned, the combined application of soil micromorphology, soil chemistry and phytolith analysis is a recent development in the study of urban and domestic space. In Africa, geoarchaeological techniques, such as soil micromorphology and soil chemistry, have elucidated aspects of prehistoric occupation at cave sites (e.g. Goldberg et al. 2009) and experimental applications have identified microscopic markers of domestic activities (e.g. Shahack-Gross et al. 2004). The presence and use of plant resources at African sites have often been investigated through the study of macrofossils (seeds, charred wood) and pollen. On the other side, phytolith studies have so far been mostly confined to environmental reconstruction with or without reference to human activities (e.g. Barboni et al. 1998; Bremond et al. 2008), and few cultural deposits (Lejju et al. 2006).

The results discussed in the present paper illustrate one way soil micromorphology and chemical analyses can be integrated with the study of phytoliths to address the use of space in urban sites, such as ancient Songo Mnara. The application of an integrative approach widens the range of information obtainable and allows refining our understanding of the archaeological record, site formation processes, resource exploitation, and the use of space. The research presented in this paper moves forward from previous studies by applying the same suite of techniques in open space and indoor contexts at the site.

Chemical and phytolith mapping shed light on distribution patterns, some of which can be associated with other archaeological findings, highlighting a diverse utilisation of both open and domestic areas. The presence of sectors of possible stabulation near the houses, interspersed with what might have been garden plots or orchards (pockets of organic-rich, dark brown silty loam) points to an articulated use of the open space between the buildings.

The plaster analysis helped in characterising some of the building materials used at the site (quicklime plaster) and their production processes.

Further research should ascertain and map the distribution of the dark brown silt sandy loam across the island, with particular reference to marginal areas (where archaeological evidence is absent or less prominent). This material is associated to the ancient settlement and land uses (vegetable gardens or orchards), rather then being related to geological discontinuities within the coral reef bedrock. Phytolith analysis indicated the presence of different grass types and a patterned distribution of woody plants. A programme of intensive archaeobotanical study and the building of reference collections is currently undergoing to unravel the types and uses of plant resources at the site.

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